ULTRA GRAVITY DRY FRACTION SYSTEM

BACKGROUND OF THE INVENTION

Many semi-solid mixtures such as animal wastes, food pastes and industrial slurries require a system that resists plugging due to their agglomerating and adhesive behaviors. Similarly, the presence of pathogens in many of the organic mixtures necessitates either high temperatures or chemical treatment. High temperatures that will destroy pathogens also will deteriorate proteins and other heat labile components. Chemical treatments are typically expensive requiring high capital cost equipment and high operating costs for additives.

The typical processes used for these applications involve many expensive pieces of equipment, high vacuum, steam generation and many interstage steps that use a variety of mechanical material conveyors. Inherent with sticky, heat labile products are attendant issues with septic agglomerations in the process. In order to eliminate these problems the Ultra Gravity dry Fraction System (UGDFS) was developed.

The basis for the UGDFS is simplicity, avoiding impingement points, high heat and the use of chemical additives. The first point of design is the creation of a system that is under high vacuum as this allows the evaporation of liquids from solids to occur at low temperatures. The second point of the design is to create a fluid bearing near the wall of the equipment parts, ducts and cyclones that are composed of ultra high velocity fluids that even in the gas phase behave as incompressible fluids. Third, having demonstrated that the incompressible fluid bearing maintains a free flow that prevents contact with the inner surfaces of the vessels a centrifugal and centripetal force balance can be achieved

with fluids that are effectively suspended on a fluid bearing. This fluid bearing, since it moves at a higher velocity than the fluid being carried does not erode the energy of the carried fluids but takes advantage of the viscous forces to increase the energy of the fluid being carried. The shear surfaces of the carrier boundary fluid and the carried fluid then transfer energy to the carried fluid. By accelerating a thin film near the wall of any vessel that contains a fluid mixture then the bearing is not destroyed by friction drag due to viscous forces.

SUMMARY OF THE INVENTION

The invention is based on the combined three principles, as mentioned above. The primary objective of the invention is drying the solids. Drying the solids is really effected by separation of the fluids from the solids by flashing the wet solids as they pass from atmospheric pressure to high vacuum and elevated temperatures. This involves the relation of mass transfer of fluid in the liquid state into a dilution fluid. This is extraction by flash evaporation. The amount of fluid that can be carried away by the dilution fluid is fairly well represented by Dalton's law. That is: " the partial pressures of the vapors in the system are proportional to their molar volumes in the system and the sum of the partial pressures of the components in the vapor phase equal the total pressure of the system". Dilution air is allowed to enter the system under vacuum. The precise point of evaporative drying is selected according to the system optimum, where the energy required for vacuum pneumatic conveying of the slurry and the energy required for heating the system are balanced. The higher the density of the pneumatic compelling air the lower the energy required for pneumatic conveying. The lower the density of the compelling air the lower the evaporation temperature of the system and the greater the

dilution fluid's capacity for removing fluids from the solids. The system is therefore designed by selecting the optimum carrying velocity for the pneumatic conveying of the slurry. Then the minimum temperature is ascertained for the vacuum (or total absolute pressure of the system). An iterative approach is then used to design a piece of equipment that will move the solid liquid mixture at the minimum carrying velocity but that will operate at a low enough temperature (which means a high enough vacuum) such that the heat labile components are not destroyed. The optimum sizes and process variables are then included in the design. Superimposed on this design then is the consideration of the high-speed boundary air that is introduced in parallel to the flow of the solid/liquid mixture. This reduces the wall friction component of the pneumatic conveying part of the design. It also adds a flashing effect of the liquids in the carried fluid/solid mixtures into the boundary fluid carrying the solids in a fluid solution. This flashing is the result of both the reduced pressure of the boundary fluid compared to the solid/liquid fluid mixture but also a shear effect due to the relative velocities of the fluids. The relative velocity of the boundary or bearing fluid to the carried solid/liquid/fluid is designed to be Mach 1+. The boundary or bearing fluid is accelerated to hypersonic speeds through the use of venturis that are fashioned such that their discharges are geometrically oriented to follow the inner surfaces of the vessels with the solids/fluid mixture held between them and the vessel walls. As a fluid is accelerated to higher speeds, approaching Mach 6, they become increasingly harder to compress. Ultimately the fluid bearing approaches incompressibility, allowing the solid/fluid mixture to circumvent elbows, curves and mild discontinuities. This effect also allows for accelerations of the materials in the center of a duct, wherein the solid/fluid mass is

carried by the fluid bearing in a vacuum that would be impossible otherwise. Third, there is an apparent 'Bose-Einstein condensate' formed in the duct and the vessels. The particles conform to a flow pattern and maintain this pattern in flow and the effects of turbulence are eliminated also eliminating particle/particle contact or abrasions. This has been observed by allowing the inner flow pattern of the duct to be exposed through a transparent barrier to a strobe light. The observed behavior stimulated the need to generate a contact surface for the pulverization of the particles. Hence, the 'static pulverizer' was invented. A circular disc, machined to a conical face of low angle was introduce inside a venturi-shaped duct such that the particles would impinge on the face and be carried around the face by a smooth airflow. The impingement reduces the particle sizes by impact fracture at speeds near 80-100 mph. The principle of reflux was then superimposed on the above principles. Thereby creating a multiplicity of fracturing, pulverizing repetitions on the average distribution of solids in the system at a given moment. In order then to allow for classification step a series of cyclones was designed such that only particles that satisfied the cut-point criterion of the final cyclone would be allowed to escape the recycle loop. This implied the return of all material, which did not satisfy the cut-point criterion of the final stage would recirculate until it achieved this criterion. Balancing the system such that sufficient recycle loop capacity existed to allow for the ultimate comminution and drying effect required empirical data be gathered. By developing a series of prototype systems, an algorithm was developed that satisfies the equations of particle size and dryness with recycle loops. This turned out to be a reflux ratio of approximately 3x the net mass inlet flow for the recycle flow for materials having 65 – 85% water content by weight.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1,2 are the combined schematic of the apparatus. Figure 3 illustrates the coaxial venturi. Figure 4 illustrates the static pulverizer.

Figure 1 shows the drying part of the process. The solids are fed into a hopper (2) from transport, truck or rail (1). A shaft-less screw conveyor (3) carries the solids to a rotary airlock (4) which dumps the solids into a central mixing chamber, which back-mixes the wet and partially dried solids. The mixed solids are passed through a rotary airlock (6) which allows the solids to be sucked through a pipe that is fitted with a coaxial venturi (12), which prevents the solids from touching the inner wall of the pipe and provides liquid extraction into this dilution air, figure 3, then the solids impinge on a static pulverizing disc (13), figure 4. The solids are split around the pulverizing disc with some comminution of the solids occurring while others pass freely around the disc. The first stage of drying/ classification occurs in cyclone (16) where the uncrushed and wetter solids return to the bottom of the cyclone and those solids, which have been sufficiently dried, are drawn to the top. The heavier solids return by a rotary airlock (17) to the central mixing chamber to be back-mixed with the wetter and drier solids. A parallel flow of clean dry, hot air enters the cyclone through a venturi and impinges on the cyclone wall behind the flow of solids from the recycle loop preventing the solids from touching the wall of the cyclone and extracting moisture from the solids as dilution air. This air is heated by the combustion in a burner (8) of fossil fuel gas or other fuel (9). The air is heated to a temperature higher than the saturation temperature of the vapor in

the solids at the design vacuum. The volume of air required to carry all the moisture from the liquids determines the size of the vacuum pump (36), figure 2. The drier and smaller solids are pulled upwards through a pipe (18) to the second stage of drying and separation. The second cyclone (21) is similar to the first with the exception that it is smaller in diameter causing high 'g' forces to be exerted on the solids, which destroys the pathogens in the solids. A parallel flow of clean dry hot air also passes through a venturi and impinges on the wall of the cyclone preventing contact of the solids with the wall. This parallel airflow also extracts more liquid as dilution air. The heavier solids now fall to the bottom of the second cyclone and through the rotary airlock (22) to the central mixing chamber to be back-mixed with the wetter and dryer solids for recirculation back through the system. The lighter, drier and smaller solids are pulled to the top of the second cyclone (22) and carried in a pipe (23) to the third cyclone (26). The third cyclone is the same as the second in diameter and has a parallel inlet of hot, dry air that keeps the solids from impinging on the cyclone walls. This is the third drying and purifying stage. The heavier solids are returned to the central mixing chamber through a rotary airlock (27) and these solids are back-mixed with the wetter solids and recycled through the pipe to the pulverizer and the three series cyclones. The drier and smaller solids are passed over the top of the cyclone to the dust collectors, Figure 2 (29,33). The first dust collector is a high efficiency cyclone. This cyclone separates the heavier solids into a bulk bag (30) through a rotary airlock. The fines are pulled through the top of the cyclone by a pipe (31) and sucked through a fabric filter (33). The dilution air, which has been cleaned of solid particles, now is pulled into a liquid-ring vacuum pump (36). The liquid ring vacuum pump discharges into a separator (37), which separates the liquid

from the gases. The liquid portion falls down into a pipe and is pulled by a centrifugal pump (46) through a pipe that has a flow control valve on it (39) and pushed to a recycle tank (47). The separator allows the saturated gases to escape from the top and be passed through a pipe (38) to a liquid ring compressor (40). The liquid ring compressor discharges into a pipe (41) to a separator (43), which allows the gases to escape from the top to a stack (44) and the bottoms are sent through a pipe with a control valve (45) to the recirculation pump (46), which pushes the liquid to the recycle tank (47). The water that is used for the seal water for the liquid ring vacuum pump and compressor becomes saturated with aqua ammonia and other condensable vapors, especially water and this increases in concentration in the recycle tank (47). The liquid in the recycle tank is pulled from the tank by a centrifugal pump (49) through a pipe with a flow control valve (48). This liquid is pushed through another control valve (50) and cooled through a heat exchanger (51). The recycled liquid now returns to the liquid ring vacuum pump (36) and liquid ring compressor (40). The heat exchanger is cooled with water through pumps (53), (56) through control valves (54), (55) utilizing process water and fresh water mixed. The water that has been separated from the liquid ring vacuum pump and liquid ring compressor eventually reaches a marketable concentration of aqua ammonia and is then tapped and drawn through a pipe controlled by a valve (57) and sent to truck or rail tankers for marketing.

DETAILED DESCRIPTION OF THE INVENTION

The flash evaporation of water from solids is carried out by allowing the wet solids to be introduced to a high vacuum environment where the temperature of the liquid inside the solids is at a higher temperature than the vaporization temperature of the liquid in the

vacuum. In order to maximize this evaporation rate of liquids from the solids the mass transfer rate must be maximized for the liquids to be taken up into the dilution air around the solids. Therefore solids must be reduced to the minimum size and the air velocity must be at a maximum near the surface of the solid particle. The limitations of particle size and maximum air velocity are affected by the ability to crush the solids, classify the solids and accelerate the dilution air to a maximum without impingement on the inner surfaces of the equipment causing wear and plugging or particle carryover. The dilution air also will draw any aerosols and condensable vapors from the solids. The dilution air is the air that goes into the system from the outside such that the solids have intimate contact with it and that the liquid in the solids will be absorbed into it.

The discovery of a venturi design that would create a shock wave near the inner walls of the pipes and cyclones allowed the dilution air and solids flows to rise much higher than those found in conventional drying equipment. The higher velocity of the solids in the pipe allowed for the utilization of impact on a solid surface or ablative plate such that the solids would shatter upon impact and clean the plate continuously. The concept of drawing off a portion of the dried solids while returning the wet solids to be back-mixed in the central mixing chamber was superimposed on the high velocity flow and vacuum flashing concepts. This allowed the apparatus to have a continuous flow of a steady state back-mixed dryness and particle size, only allowing the particle sizes, which were classified to the desired specifications to pass to the product collection system. The looping behavior of the back-mixed solids allowed the size of the dryer to be greatly reduced. The high velocities that can be created inside the cyclones and pipes due to the coaxial and parallel clean air as shock waves rendered very high heat and mass transfer

coefficients, allowing great reductions in the time required for drying the solids. The condensable vapors that would not come out of the system in either the cyclone or filter could be scrubbed out into the seal water of a liquid ring vacuum pump and compressor. For animal wastes the ammonia that is generated as a product of anaerobic bacteria is a valuable product in aqueous form. The seal water in the vacuum pump is limited to low concentrations of ammonia due to the high flash point of ammonia so a liquid ring compressor was hitched up in series with the vacuum pump to allow the seal water in it to rise to higher concentrations.

The system is designed in the following way:

1. A desired production flow rate is established of wets and dry solids and liquid product.
2. The solids are analyzed for liquid content.
3. The liquid characteristics are determined as to their vapor-pressure curves at varying temperatures and pressures.
4. The dilution air is deduced from the optimal system temperature and pressure by application of Dalton's law.
5. The vacuum pump is sized from manufacturer's literature.
6. The pie sizes are determined by using the pneumatic conveying nomographs found in the literature.
7. The cyclones are sized to obtain the maximum RPM or the given mass flows of solids and gases and the cut points are selected for the desired particles size and moisture content.